Validation of Human Behavior Representations

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Overview

- **Basic HBR Validation Concepts**
- **Deriving HBR Requirements**
- **Building an HBR Referent**
- **Validating the HBR Conceptual Model**
- **Validating the HBR Knowledge Base**
- **Validating HBR Results**
- **Special Challenges**

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Basic Concepts: People Hold Fast to Many Myths about Validating HBRs

A few of the myths about validating human behavior representations (HBRs) that people believe include

- **Users are good sources of requirements for HBRs.**
- **A good referent for an HBR is a human doing the same job.**
- **A valid HBR is as realistic (i.e., error = 0 in all property dimensions for all dependencies) as possible.**
- **A good HBR is stochastic just like humans.**
- **A good HBR is logical just like humans.**
- **“Fair Fight” is a clear and testable criterion for HBR fidelity.**
- **The experts will recognize invalid HBR behavior when they see it.**
- **Validating an HBR is always expensive.**
- **Validating HBRs is too hard so why do it or even try to understand it.**

Basic Concepts: HBRs Are Unique Among Other Complex Simulations

HBRs appear distinguished from other parts of a simulation by their

- **Very high inherent complexity,**
- **Numerous nonlinear relationships all interacting chaotically over many different orders of magnitude, and**
- **Complex coupling with other parts of a simulation system.**

However, simulated environment and nuclear effects models both face similar problems. The real distinction of HBRs comes from their knowledge bases.

- **The knowledge base really constitutes a computer program, in many cases a very complex one, that the engine executes.**
- **An HBR's knowledge representation defines its programming language.**
- **A simulation system that represents different humans contains many of these computer programs within computer programs.**
- **Developers must thus debug two sets of computer programs: the engine (usually written in a language like C) and the knowledge base for each individual represented (written in the knowledge representation language).**

These facts added to the inherent complexity of HBRs easily make them the most complex components of a simulation system, even when compared to simulated environments.

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Basic Concepts: Validating HBRs Present Several Challenging Problems

These validation problems for HBRs exist because they

- **Interact with complex environments**
- **Deal with very large behavioral hyper-spaces**
- **Inherently involve nonlinear behavior**
- **Use oblique model representations**
- **Couple effects over many orders of magnitude**

Advancing technology will only aggravate these problems!

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Basic Concepts: Immature Technology Hampers HBR Validation

Factor	Maturity
Theory	• Almost none, if any, on validation of HBRs specifically • Considerable psychological, sociological & physiological theory on how actual humans behave under various circumstances • Considerable theory on testing/observing human and group behavior (some of which may be useful)
Tools & Techniques	• Some tools for generating execution traces for some HBRs (e.g., Soar) • Some tools to display observable HBR behavior (e.g., PVDs) • Many tools for KBS validation
Experience	• Some limited direct experience in validating HBRs for various purposes (e.g., Soar, ACT-R, HOS, MicroSaint) • Much experience in validating KBSs for various purposes
Experimental Data	• Much on performance of actual humans for a variety of tasks • Much from psychological, sociological and physiological experiments on actual humans

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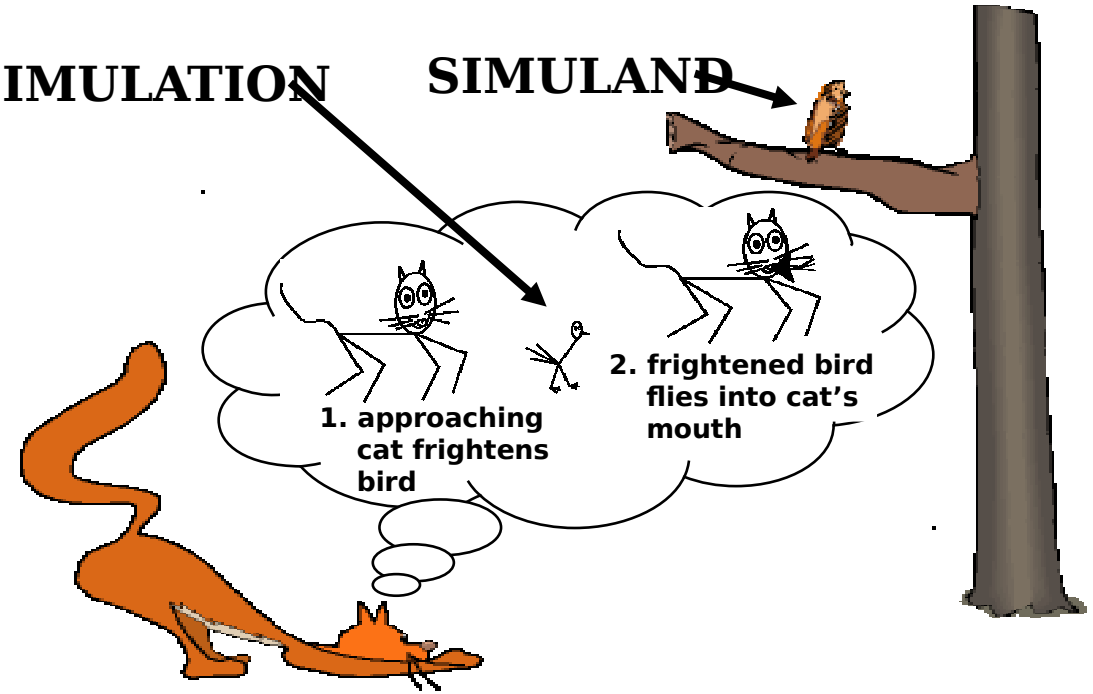
Basic Concepts: Simulations Only Resemble Their Simulands

Everyone knows that, unique among systems, simulations abstractly represent the behavior of something else for some purpose. But, since simulations necessarily omit some of the details about the things they model from



"How closely must a simulation resemble its simuland to achieve a particular purpose?"

The ability to answer this question will also address such related questions as "Can a particular existing simulation achieve a purpose for which it was not originally designed?" and "Can a federation of simulations achieve some given purpose?"

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Basic Concepts: Validation Answers the Question "How Closely Must the Simulation Resemble Its Simuland?"

Validation answers this question by assessing the fitness of a simulation for a particular purpose.

The reliability of this assessment and the answers it supplies depend upon the quality of three types of information:

- **Validation criteria,**
- **Referent, and**
- **Simulation capabilities.**

But, getting this information with the quality needed can be challenging, especially for simulations of such complex phenomena as HBRs.

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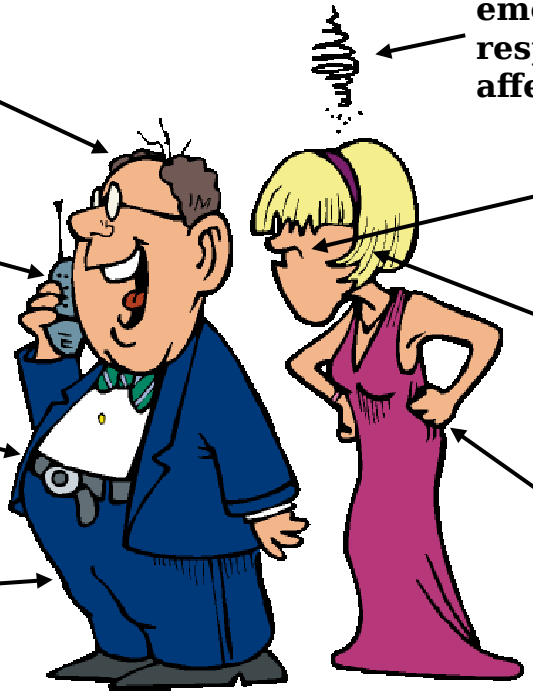
Basic Concepts: All HBRs Model the Behavior of People at Some Level of Abstraction

HBRs can model any combination of the different facets of human behavior including



The terms computer generated forces (CGF), semi-automated forces (SAF and SAFOR), synthetic forces, automated forces (AFOR) and command forces (CFOR) all refer to different forms of HBRs.

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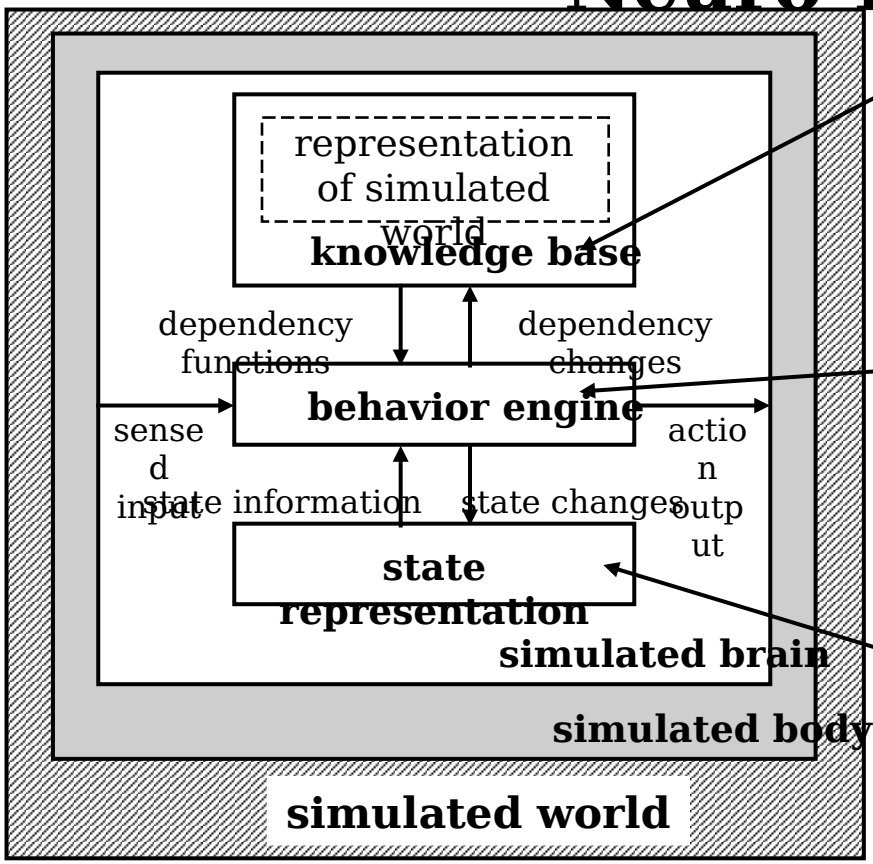
Basic Concepts: HBR Canonical Model Illustrates the Basic Components of Neuro-Behavior



Knowledge Base = { executable dependencies needed to create the internal state representation from sensory input & respond to that state, decision functions that determine when & which of those dependencies should be executed to achieve goals }

Behavior Engine - chooses the dependencies from the knowledge base appropriate to the current state & executes those dependencies to modify the internal state representation or generate the actions to achieve the HBR's goals

State Representation - the HBR's dynamic assessment of both the internal & external world state including goals

This partitioning creates the flexibility needed to represent the behavior of different individuals performing in different roles without requiring the building of completely new execution infrastructures each time.

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Basic Concepts: All Behavior Engines Perform Essentially the Same Functions

All HBR behavior engines basically perform the following functions in one form or another:

- **Accept input about the state of the simulated world & use that information to update the HBR's internal state representation**
- **Evaluate the decision functions in the HBR's knowledge base, in the context of the internal state representation changes, to identify the executable dependencies relevant to the current situation and goals**
- **Executes the appropriate dependencies to**
  - ➤ **Change the internal state representation &**
  - **Generate the actions needed to achieve the HBR's goals**

In other words, in the context of this model, the only things an HBR can do to manifest its behavior are change the contents of its internal state representation, knowledge base, and output.

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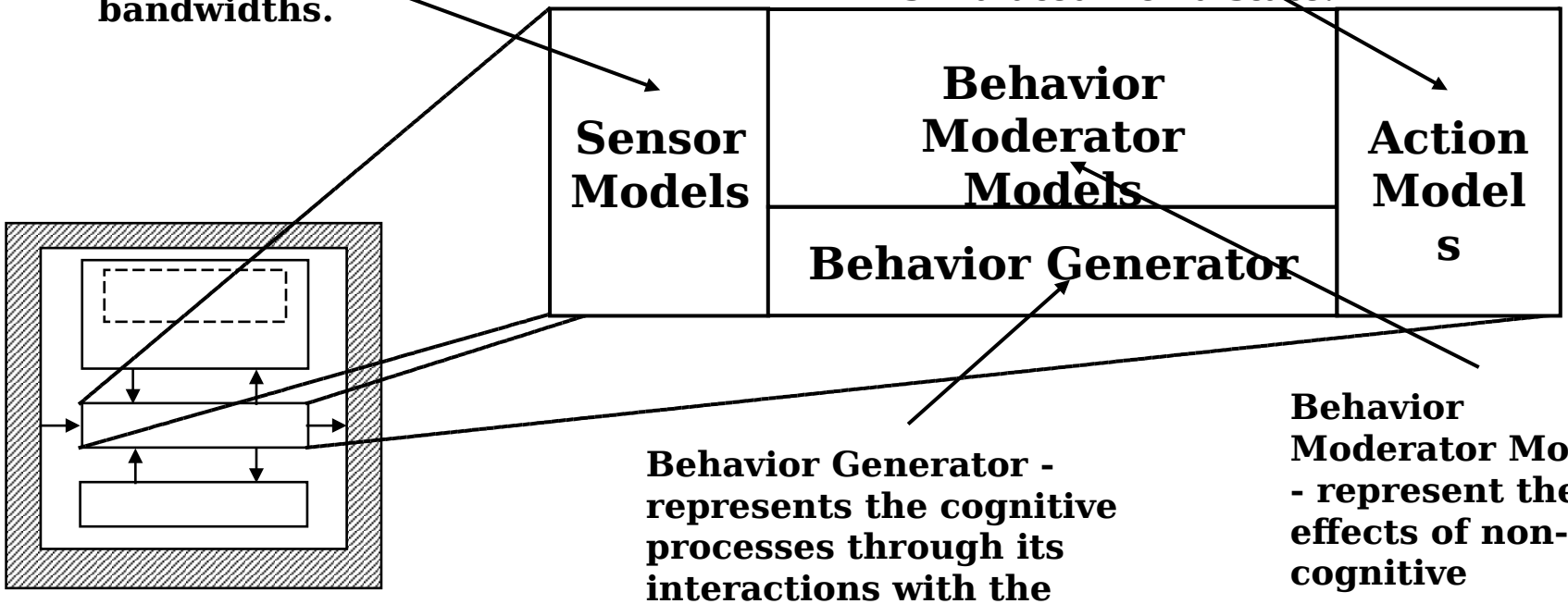
Basic Concepts: Behavior Engines Can Be Partitioned into a Few Components

Sensor Models - couple the HBR to the information available from the simulated world. They represent input modalities and bandwidths.

Action Models - couple the HBR brain to the simulated world through the body's effectors (I.e., muscles). They represent the actions taken to change the simulated world state.



Behavior Generator - represents the cognitive processes through its interactions with the knowledge base and state representation. The behavior moderator models modulate its

Behavior Moderator Models - represent the effects of non-cognitive processes upon the cognitive processes.

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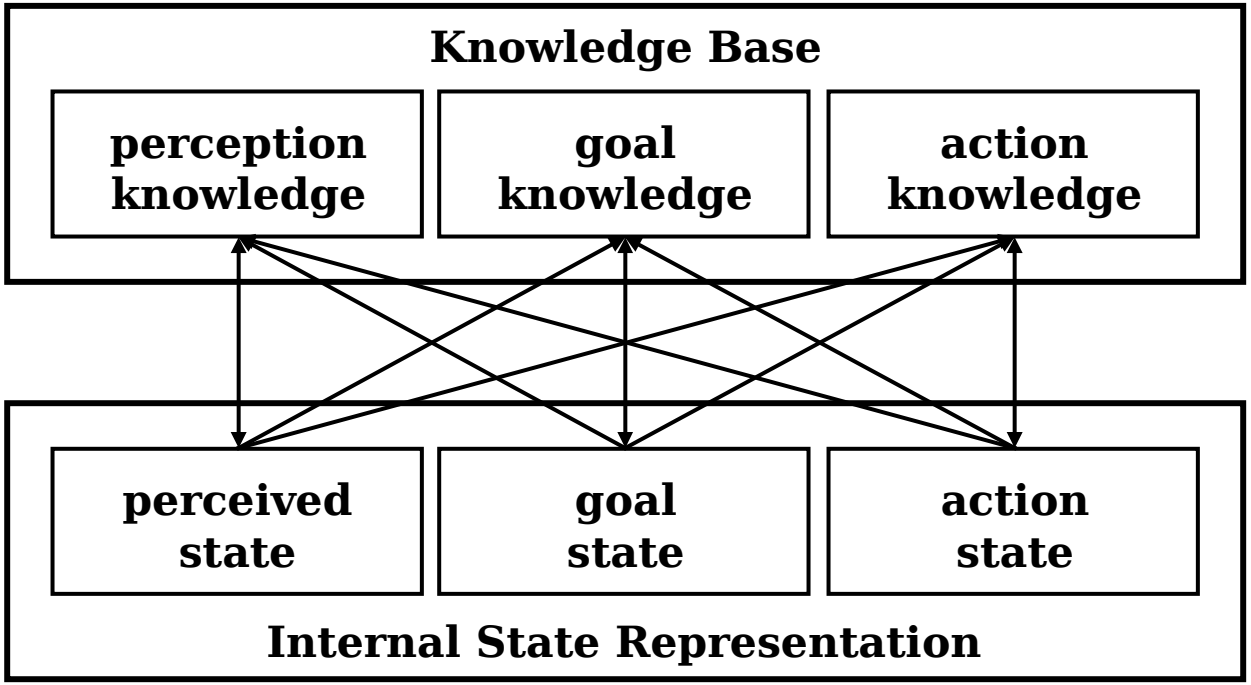
Basic Concepts: Knowledge Base & State Representation Have the Same Information Partitioning



The arrows going from the internal state to the knowledge base represent independent property flows & those going from the knowledge base to the state representation are the dependent property flows.

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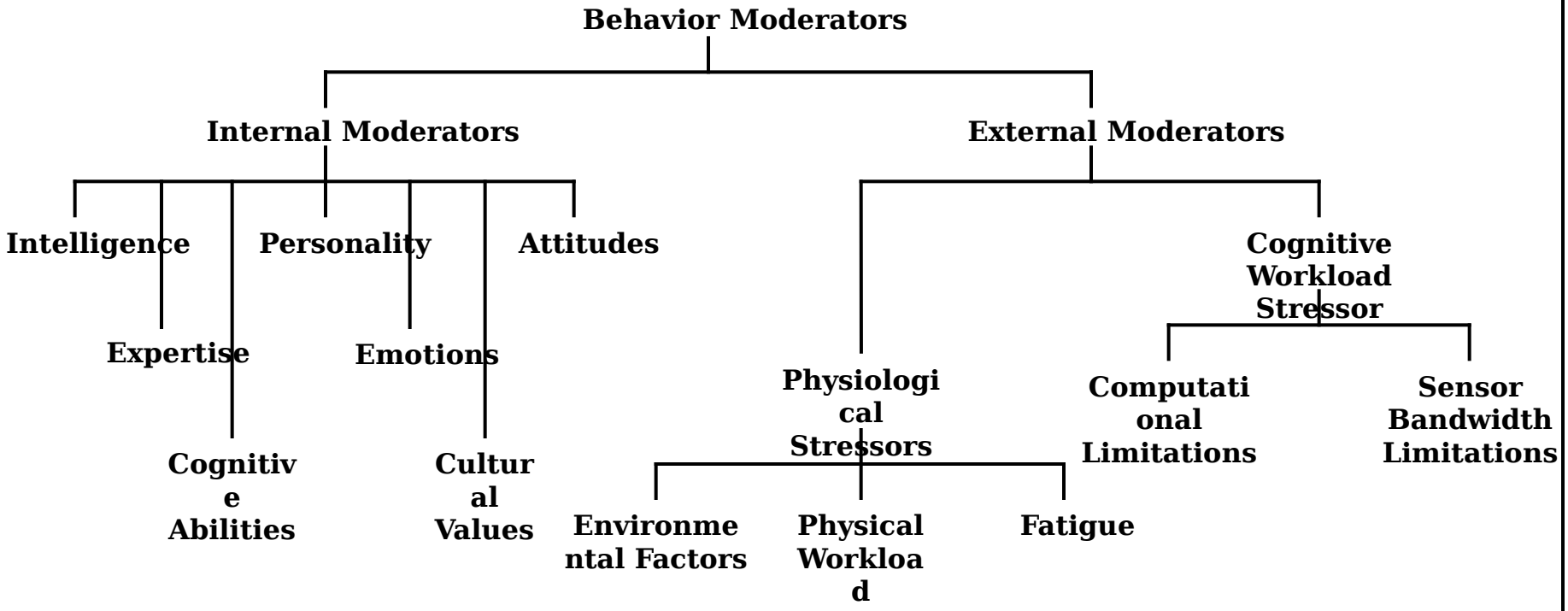
Basic Concepts: Behavior Moderators Modulate Cognitive Functions

A behavior moderator is a condition that affects human behavior in ways other than those affected by the cognitive elements.



Few, if any, consistent models exist that describe how the behavior moderator conditions actually change brain function &, in turn, human behavior.

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Basic Concepts: HBR Behavior Engine Dependencies Can Be Organized into 3 Function Groups

- **Knowledge base element execution (e.g., theorem proving, condition matching, and conflict detection and resolution)**
- **Emotional effects manifestation (e.g., computing emotional state, determining emotion influences upon performance limits, & computing influence probability distributions)**
- **Performance limit representation (e.g., sensor & computational bandwidth constraints upon the observed behavior)**

Behavior engine dependencies only include the functionality that manifests emotional effects & performance limitations when their HBR designs do not embed those representations into their knowledge bases.

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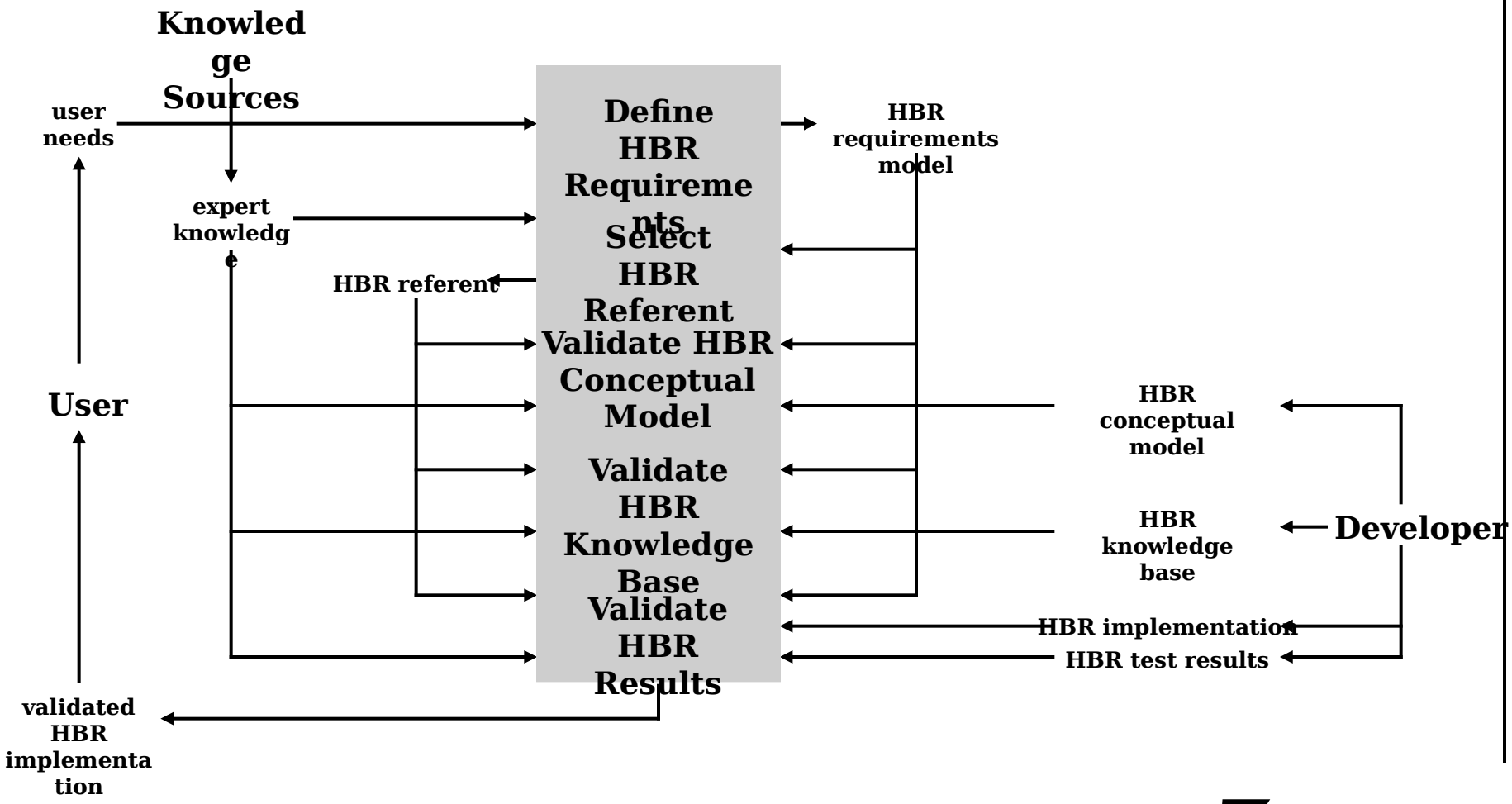
Basic Concepts: The Flow of Information from Several Sources Fuels the Basic HBR Validation Tasks



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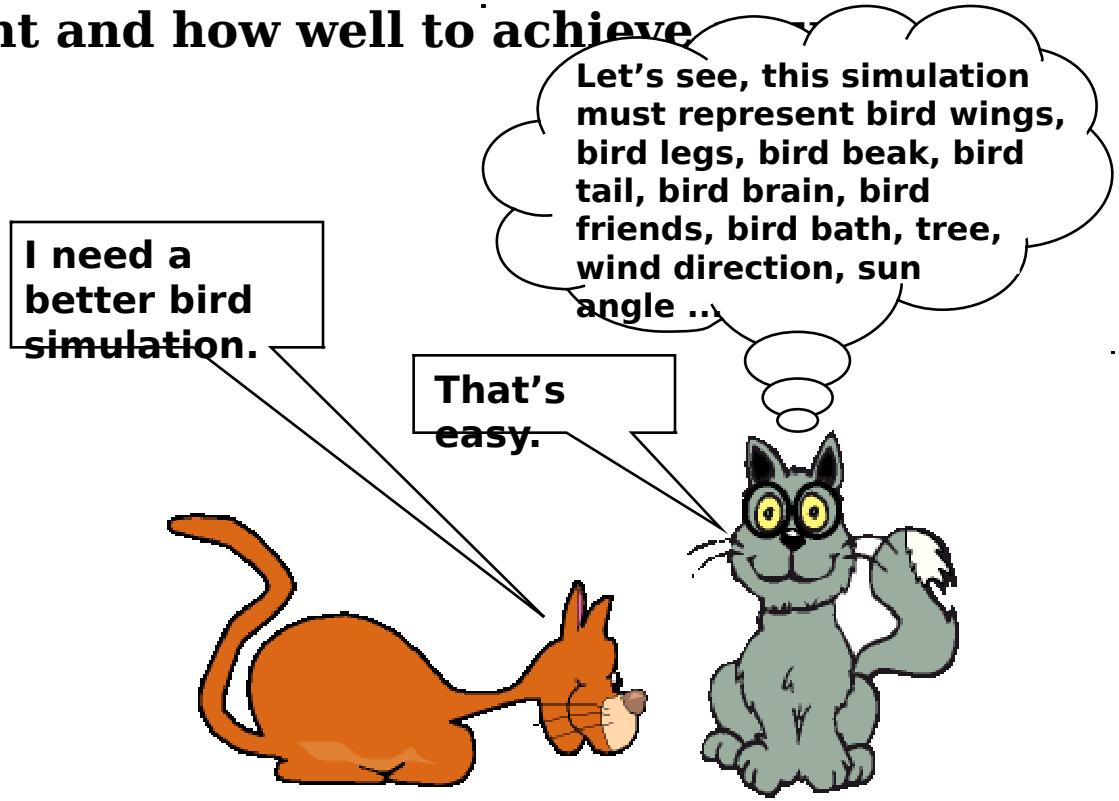
Requirements: Validation Criteria Elaborate the Required Simulation Capabilities

Validation criteria, derived from the user's purpose for a simulation, detail the minimum simulation capabilities needed to achieve that purpose. These criteria define what a simulation must represent and how well to achieve it.

Often subject matter experts (SMEs), working for the user or the developer, derive detailed validation criteria for a simulation from very limited user input. These derivations depend upon the SMEs' own subjective opinions of what simulation capabilities the users really need. This subjectivity can decrease the reliability of the resulting criteria and any simulations built to satisfy them.



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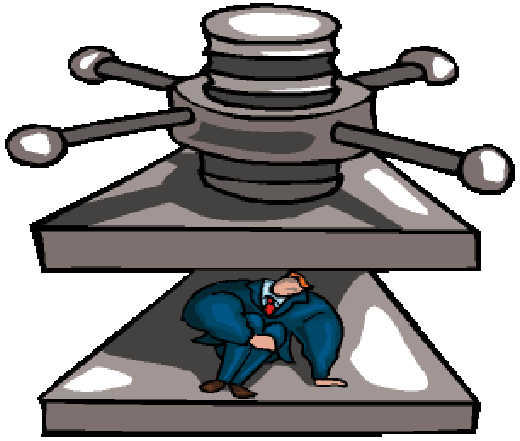
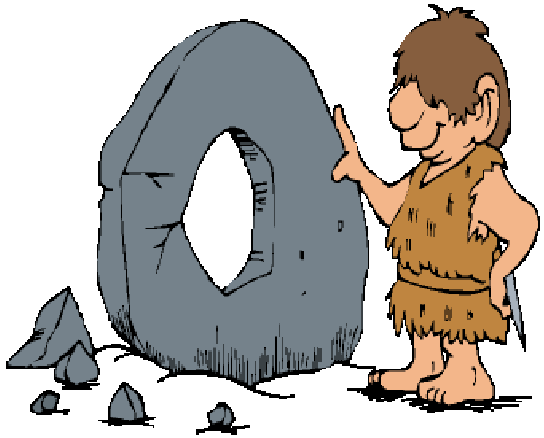
Requirements: Collecting User Needs Isn't the Easiest Part of Deriving Validation Criteria

If asked, most Users DON'T need HBRs. So, three options exist for collecting those needs:



PRESSURE THE USER



INVENT THEM

DERIVE FROM AUTOMATION NEEDS

Most needs for HBRs come not from users but first from the practical need to decrease operations costs by replacing human role players with automation then from the need for consistent doctrinally correct behaviors..

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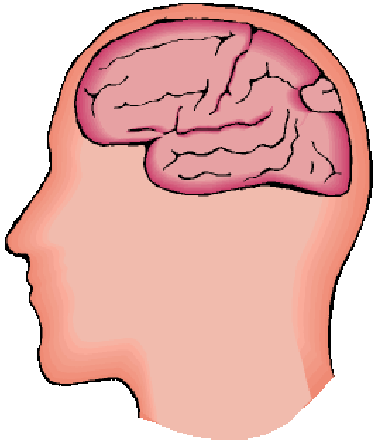
Requirements: Three Categories Broadly Partition HBR Capabilities

Human Representation

Non-Cognitive Factors

Human Roles
(e.g., Military Functions)

Cognitive Capabilities



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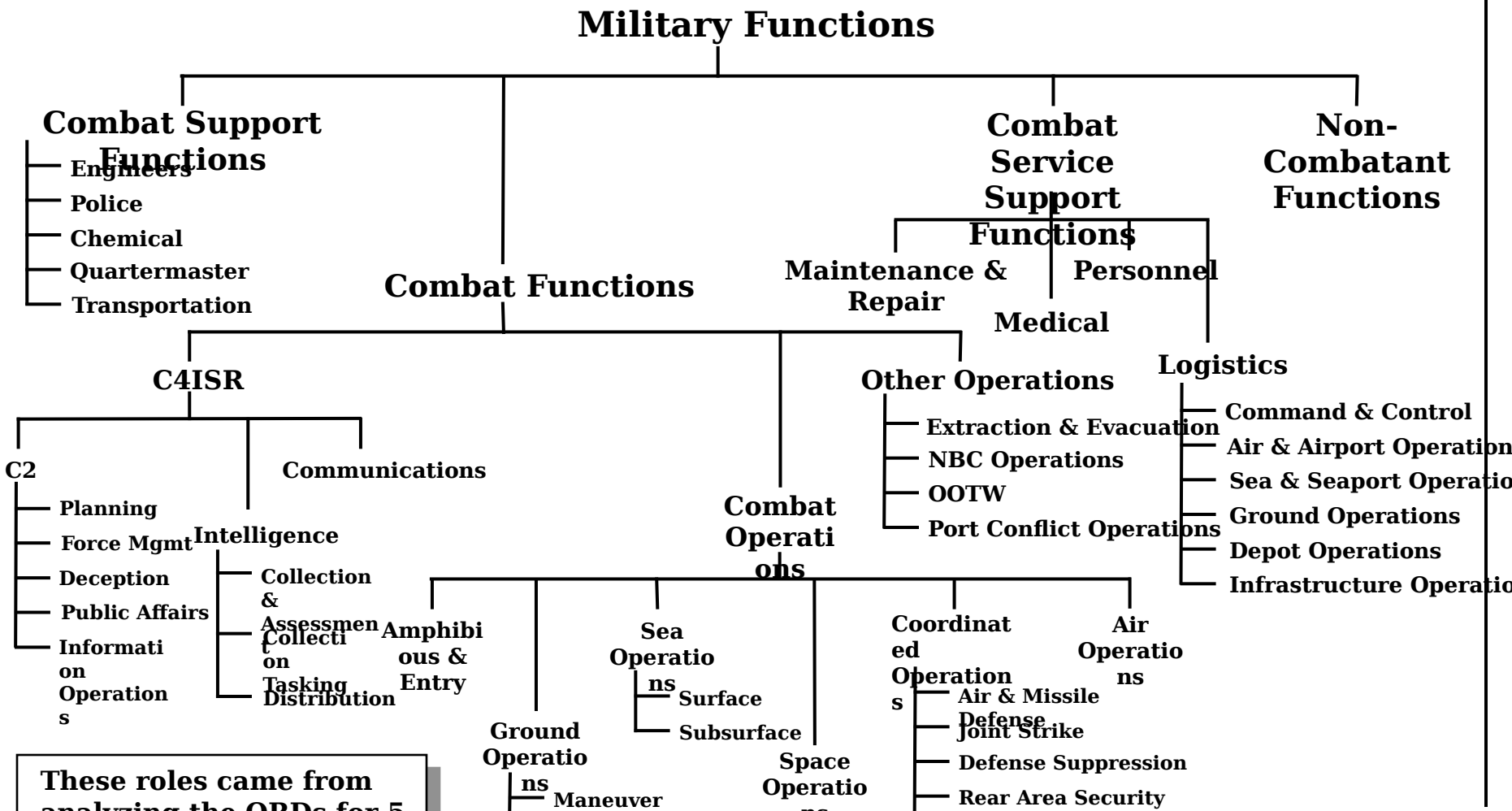
Requirements: Human Performing Military Functions Exemplify Role Identification



These roles came from analyzing the ORDs for 5 military HBRs.

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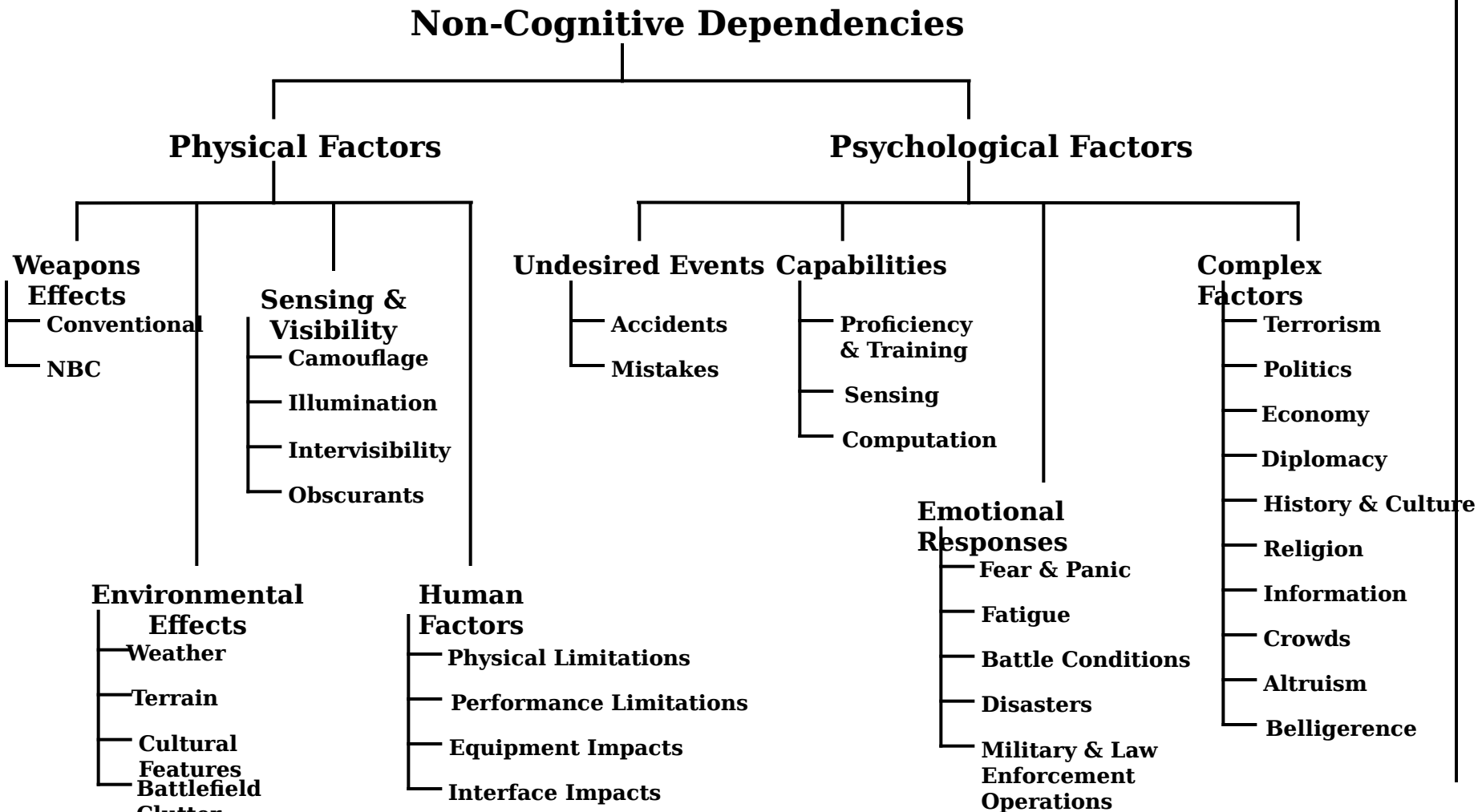
Requirements: Non-Cognitive Dependencies Represent the Less Popular Side of Human Behavior



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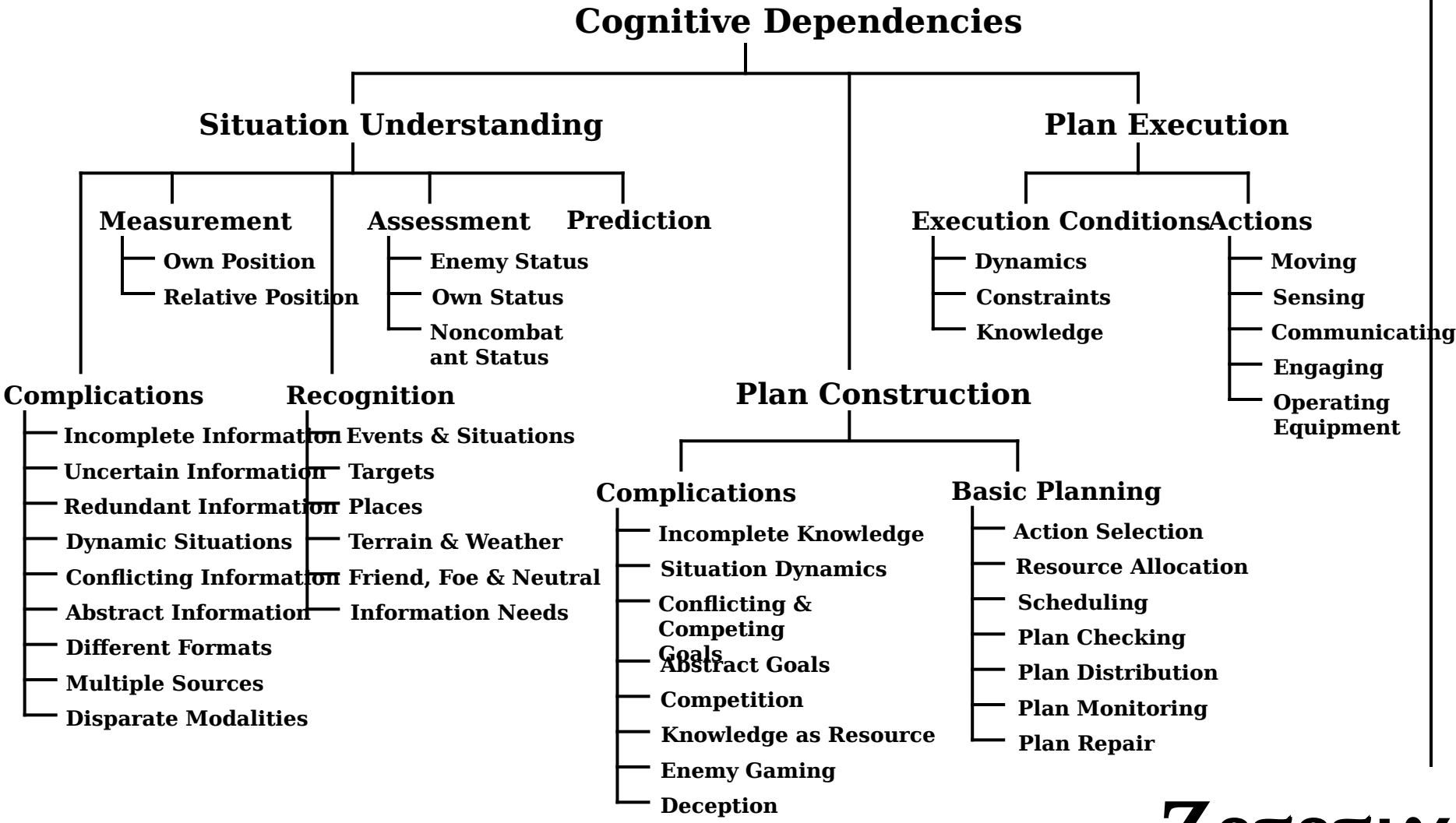
Requirements: Cognitive Dependencies Represent the More Popular Aspects of Human Behavior



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Requirements: Lessons Learned from Practice

- **Poor HBR requirements specifications create a domino effect of barriers to achieving HBR validity.**
- **Validation decisions cannot be defended without the effects and performance requirements that drove the implementation.**
- **Requirements specifications usually do not provide effects and performance measures.**
- **Some acquisition approaches purposely avoid specific requirements.**
- **Lacking any other specification, HBR KA attempts to describe its domain from a reality perspective, using its parlance.**
- **HBR KA is too general in description, creating documents requiring developers to infer meaning and make choices of importance.**
- **Development can never achieve reality.**
- **Users and decision-makers incorrectly assume validity is related to reality instead of application requirements.**

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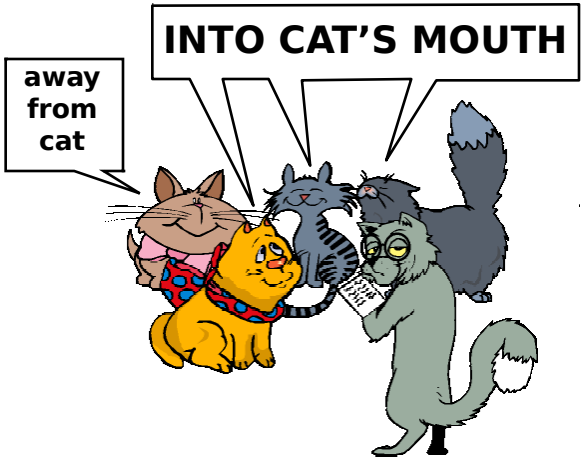
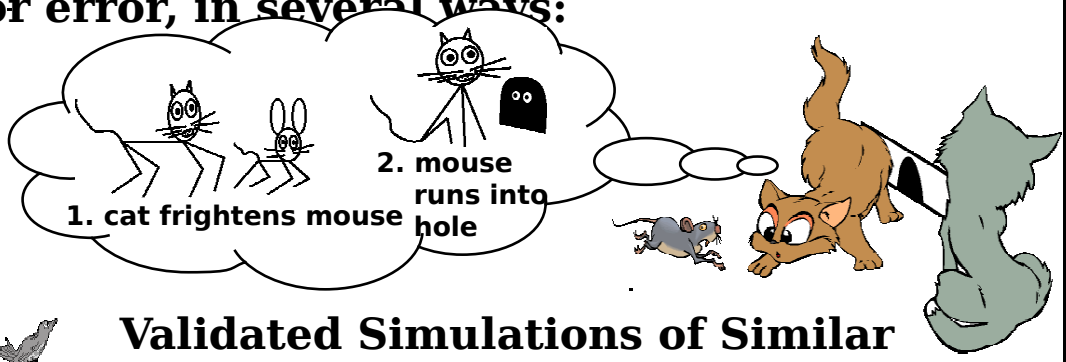
Referents: Referents Define the Standards to Gauge Accuracy

One can construct a referent for phenomena of interest, the best knowledge we have about those phenomena against which to define and measure simulation accuracy or error, in several ways:



SME Opinions

Direct Observations



Validated Simulations of Similar Situations

Theory Derived from Observations

Theory of Bird Response

Outcome	Probability
No response	0.05
Fly away from cat	0.95
Fly into cat's mouth	0.00

The most commonly used but, by far, the weakest referent knowledge comes from SME opinions.

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Referents: Referents for HBRs Can Come from Several Information Sources

Good News: **Human behavior is a well studied field with numerous general sources of knowledge about it.**

- **Experimental data describing human functionality and performance under well controlled or known conditions**
- **Empirical data describing human behavior under conditions ranging from unknown to well characterized**
- **Experience, knowledge and intuition of subject matter experts**
- **Mathematical models of human behavior that have been validated by experimental or empirical data**
- **Qualitative descriptions of human behavior whose validation ranges from none to extensive**
- **Other simulations of human behavior that have established credibility with the intended users and for their particular purposes**
- **Combinations of the types described above.**

Bad News: **A very complex set of phenomena generate human behavior so little good information may be available on the behavior related to specific tasks or under combinations of conditions. Further, many psychological and sociological models may exist to explain specific phenomena but they probably do not agree.**

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Referents: Six Levels Organize the Available Referents

Level	Literature Base	Available Information	SME sources
Domain	domain-specific	extensive performance data & models	domain experts
Sociological	sociology	extensive experiments, observations & models	sociologists & psychologists
Psychological	psychology	extensive experiments, observations & models	psychologists & psychiatrists
Physiological	physiology & anatomy	extensive experiments, observations & models	physiological psychologists & physicians
Computational	computational complexity	limited experiments, observations & models	mathematicians, computer scientists & physicists
Physical	physics	informal observations & limited models	mathematicians & physicists

Simultaneous testing of model correspondence at multiple levels requires model consistency b

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Referents: Both SME & Experiment Referents Have Their Pros & Cons

SME Referents:

Pros:

- **Usually broadly applicable over range of conditions that do not perfectly match their direct experiences**
- **Can deal with situations for which experiments are not possible (e.g., future warfare)**

Cons:

- **Judgments often affected by personal preferences**
- **Generally, qualitative**
- **Situation must roughly match their experience, education & skills**
- **Tendency to invent answers leading to incorrect judgments**
- **Differences of opinion difficult to resolve**

Experimental Data Referents:

Pros:

- **If properly collected and interpreted, provides insight unbiased by the personal preference**
- **Generally, represents a repeatable source thus increasing credibility**
- **Generally, quantitative**

Cons:

- **Applicability of experimental data usually severely limited by the**
  - **Size of the data set,**
  - **Extent of the controls exerted upon the conditions under which it was collected, and**
  - **Uncertainties associated with the experimental conditions, measurement, and analysis.**
- **Situation must closely coincide with experimental conditions & rich data must be collected**

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Referents: Lessons Learned from Practice with SMEs

- **Regardless of the quantity of information produced by military KA SMEs, the descriptions tend not to support the requirements of software development. In fact, the larger the quantity of information, the more difficult it is for a software engineer to infer the essential elements that need to be implemented.**
- **Validation of such KA documents has little relationship to M&S HBR validation, for the software engineers will analyze them and develop a document that suits implementation. If this approach was the only means to transform military domain information into software domain information, the software engineer's document is what should be validated. It represents what will be modeled.**
- **The more that KA documentation development processes are improved to support implementation, the greater the value of the HBR validation activities of those documents.**

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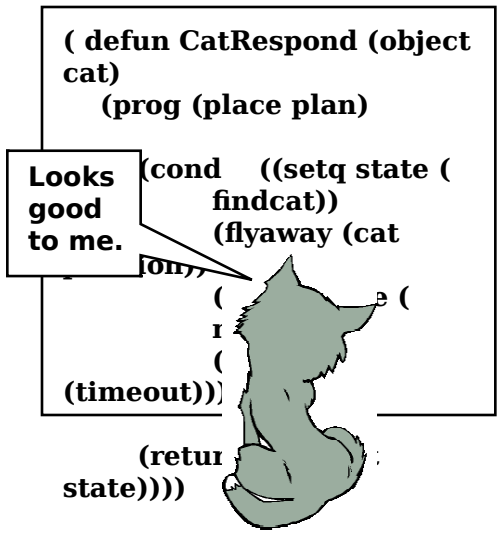
CM Validation: A Simulation's Design Provides Initial Visibility into Its Capabilities

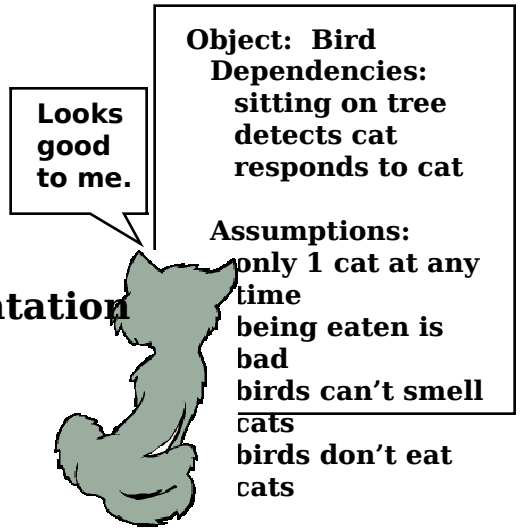
But, to obtain useful and reliable validation of an HBR design, its conceptual model must

- **Contain sufficiently rich descriptions of representational capabilities,**
- **Describe capabilities in a form accessible to evaluators, and**
- **Elucidate the assumptions underlying all representation design decisions.**

Good and bad design documentation may yield the same expert assessments but with very different accuracies and reliabilities.



Poor Design Documentation



Good Design Documentat

Good design documentation will describe the HBR's representational capabilities in the same fidelity components as used to describe the representational requirements.

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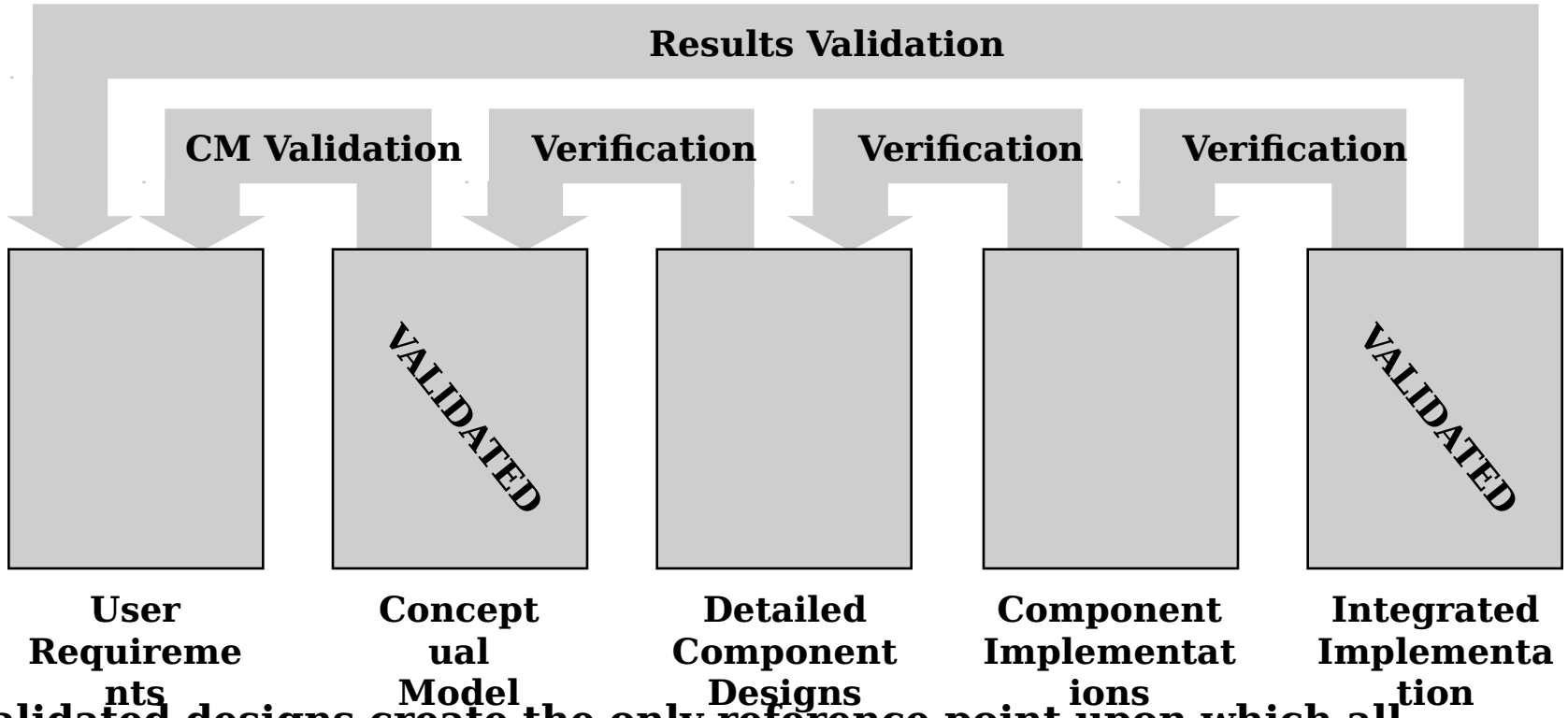
CM Validation: All Verification Rests upon the CM Validation Foundation



Validated designs create the only reference point upon which all subsequent verification efforts depend for those efforts to contribute substantially to simulation validation.

CAUTION: Even scrupulously conducted design reviews incorporate many subjective and poorly characterized elements that weaken design validation & verification assessments.

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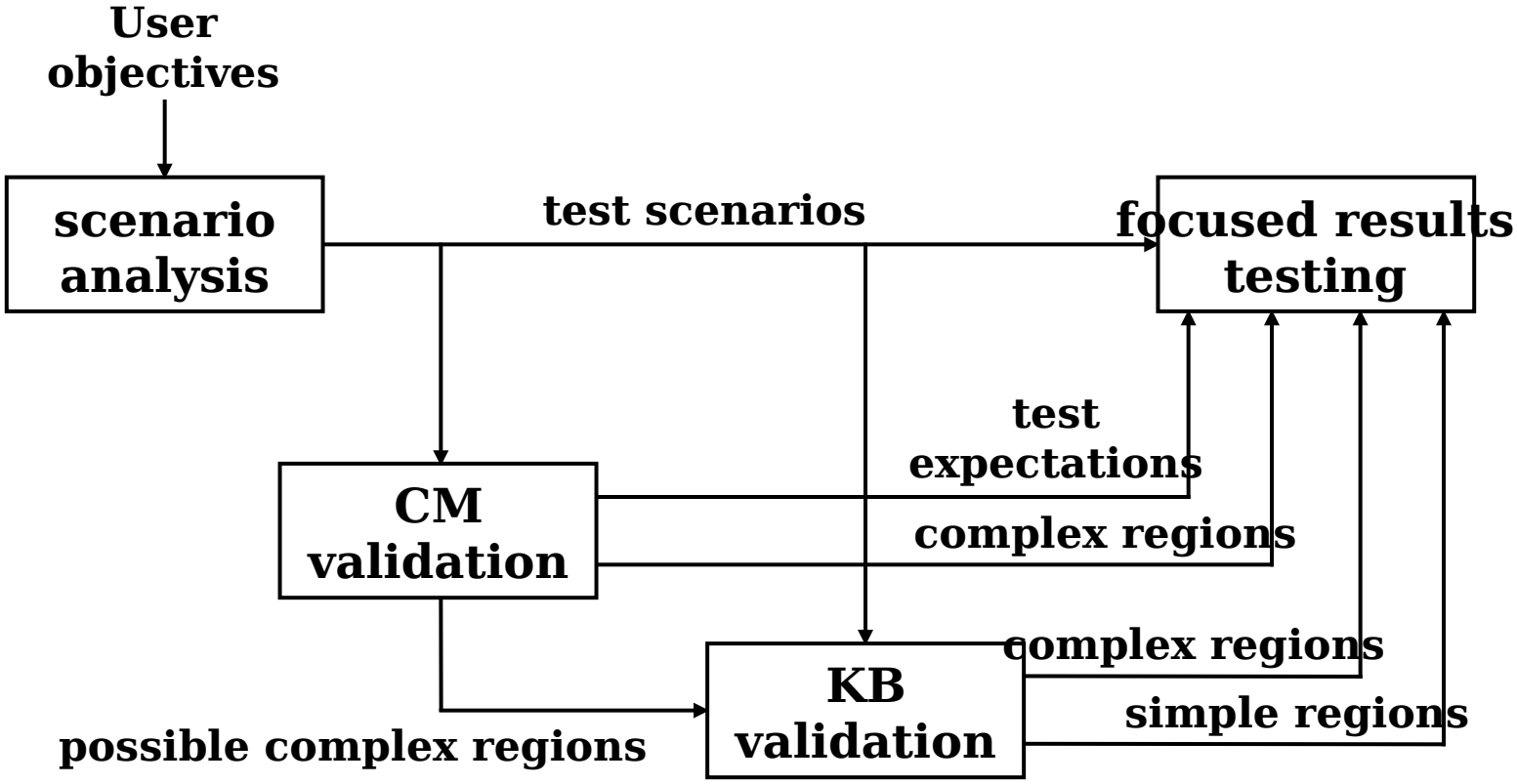
CM Validation: Conceptual Model Validation Results Can Guide the Results Validation Effort



In this framework, preceding HBR validation phases provide validation information AND information that constrains the testing space.

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CM Validation: No Tools Exist Specifically to Support Validating HBR Conceptual Models

- **Unfortunately, no tools exist that specifically support the validation of HBR conceptual models.**
- **However, some general purpose modeling tools may be applicable and may even be used by the developer.**
- **For example, the developer may have used a Universal Modeling Language (UML) tool to construct the conceptual model. The development environment supporting this description has consistency checking tools that could be useful.**
- **The developer will have further information on these and can assist in their use to support the validation effort.**
- **Also, some KBS VVE&T tools may be applicable but have not yet been applied (see next section).**

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KB Validation: The HBR's Knowledge Base Makes Essential Contributions to HBR Validity

An HBR's knowledge base essentially defines the computer program that controls the HBR's response to the stimuli it receives from the simulated world.

- **At a minimum, the knowledge base largely determines the HBR's purely cognitive behavior (i.e., unmodified by behavior moderators).**
- **It may also contribute to the manifestations of emotion upon behavior.**

Therefore, an invalid knowledge base will likely generate invalid behavior and it can <u>NEVER</u> be trusted to reliably generate valid behavior.

However, the validity of the knowledge base cannot guarantee the validity of the HBR behavior since many other components contribute to its overall validity (e.g., behavior engine, sensor and effector models, behavior moderator models).

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KB Validation: Several Factors Determine Knowledge Base Validation Difficulty

The difficulty and effectiveness of knowledge base validation depends strongly upon the

- **Knowledge base size (i.e., number of elementary components),**
- **Knowledge base complexity (degree to which elementary components are coupled to one another),**
- **Knowledge representation used,**
- **Validation methods employed, and**
- **Tools chosen to support validation.**

The selection of the knowledge representation, like the selection of a programming language, affects all of these factors.

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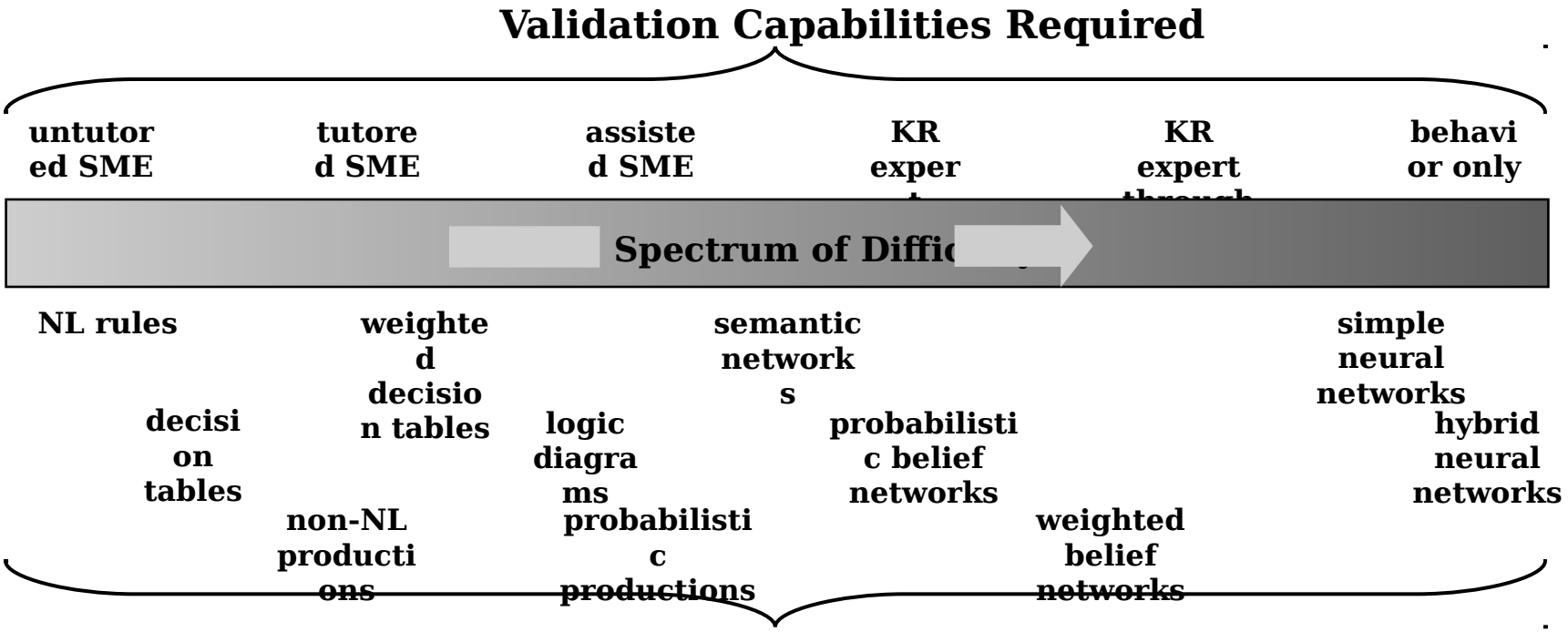
KB Validation: Knowledge Representation Accessibility to Human Scrutiny Is Key to KB Validation

Some knowledge representations lend themselves more to direct human scrutiny than others.



This illustration is only approximate and the actual validation difficulty will vary with knowledge base characteristics, specific tools used & expertise involved.

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KB Validation: Knowledge Base Validation Techniques & Tools Do Exist

Relatively little technology explicitly exists explicitly for validating HBR knowledge bases but

- **Significant resources exist to support verifying, validating, evaluating and testing (VVE&T) knowledge-based systems (KBSs).**
- **While most of these resources were developed primarily for expert systems (largely for medical applications), much of this technology has direct application to HBR knowledge bases.**
- **A search of the literature on VVE&T of KBSs identified several resources that provide good overviews of this active research area including several books and survey articles.**

KB Validation: KBS VVE&T Has a Rich State of the Art

Significant investment has gone into developing and validating KBSs to perform a variety of expert functions including diagnosis, decision support and automatic control.

State Characteristic	Number Found	Specific Aspects Studied
Theory	16 Refs.	data selection , verification, validation, testing
Techniques	50 Tech.	logic, optimization, classification, transformation, graph theory, empirical, heuristic, modeling & simulation
Tools	66 Tools	specification, verification, validation, refinement, testing, performance evaluation
Problem Areas	33 Prob.	integration, knowledge type, knowledge representation, specific architectures, V&V processes
Experience	179 Refs.	medical, financial, analytical chemistry, management decision aiding, space, telecommunications, computer design, data analysis, manufacturing, scheduling, mineral exploration, legal support, software engineering, product design, speech & text understanding, natural language generation

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KB Validation: KBS V&V Has Studied All of the Important Problems to Some Extent

Problem Category	Specific Problems Studied
Knowledge Integration	completeness/coverage, consistency/coherence, redundancy, correctness/accuracy, heterogeneity/competition, integrity
Knowledge Type	incomplete, multi-level, modular, uncertain, inconsistent, subjective, fuzzy, probabilistic, large, wide domains
Knowledge Representation	nonmonotonic, case-based, tabular, equations, weighted, control/meta-knowledge, dynamic properties, logic, frames
Specific Architectures	blackboards, expert system shells, multi-agents, neural networks, hybrids
V&V Processes	automatic refinement, knowledge base verification, evaluation criteria, real time performance, knowledge acquisition

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KB Validation: Examples of KBS VVE&T Tools

Tool	Purpose	Capabilities	Knowledge Representation	Environment
CHECK	verification	checks redundancy, conflict, subsumption, circularity, missing rules, unreachable clauses, deadends.	predicate logic	LES
COVER	verification	checks redundancy, conflict, subsumption, circularity, unsatisfiable conditions, deadends, missing rules	PROLOG-based rules	PROLOG
ESC	verification	checks conflicts, redundancies, discrepancies, ambiguities, missing rules	production rules	
KB-REDUCER	verification	checks conflicts, redundancy, subsumption	propositional rules	ONCOCIN ES
ONCOCIN Rule Checker	validation	checks redundancy, subsumption, conflicts, missing rules	production rules	application-neutral MYCIN ES
VSE	validation	checks knowledge against requirements	production rules	EMYCIN ES
TEIRESIAS	validation	displays reasoning traces	production rules	
EMYCIN	verification &validation	checks syntax & semantics & displays reasoning traces	production rules	
SEEK	verification &validation	supports interactive rule refinement	production rules	
Path Hunter/Tracer	verification &validation	selects test cases for exhaustive testing	production rules	
TRUBAC	verification &validation	combines structural & functional testing with behavior prediction	production rules	
VVR	verification &validation		production rules	

Listing these tools does not imply any endorsement of their applicability to HBR validation.

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KB Validation: KBS VVE&T Technology Has Good Potential for HBR KB Validation

- **Theory**
  - **Addresses all important problems but not completely**
  - **Exists as loosely coupled islands of concepts**
  - **Requires unifying theory of intelligent systems**
- **Tools**
  - **Many tools & techniques proposed, developed & tested**
  - **Range from single tools to integrated environments**
  - **Applicable only to models of cognitive functions**
- **Experience**
  - **Vast range of KBS validation experience**
  - **No reports of experience in validating HBRs (so far)**
  - **Much to learn from this experience**

Becoming familiar with what is available in this area that can be adapted to address different aspects of HBR validation can reduce the need, expense and time of inventing new techniques for validating models and simulations of human behavior.

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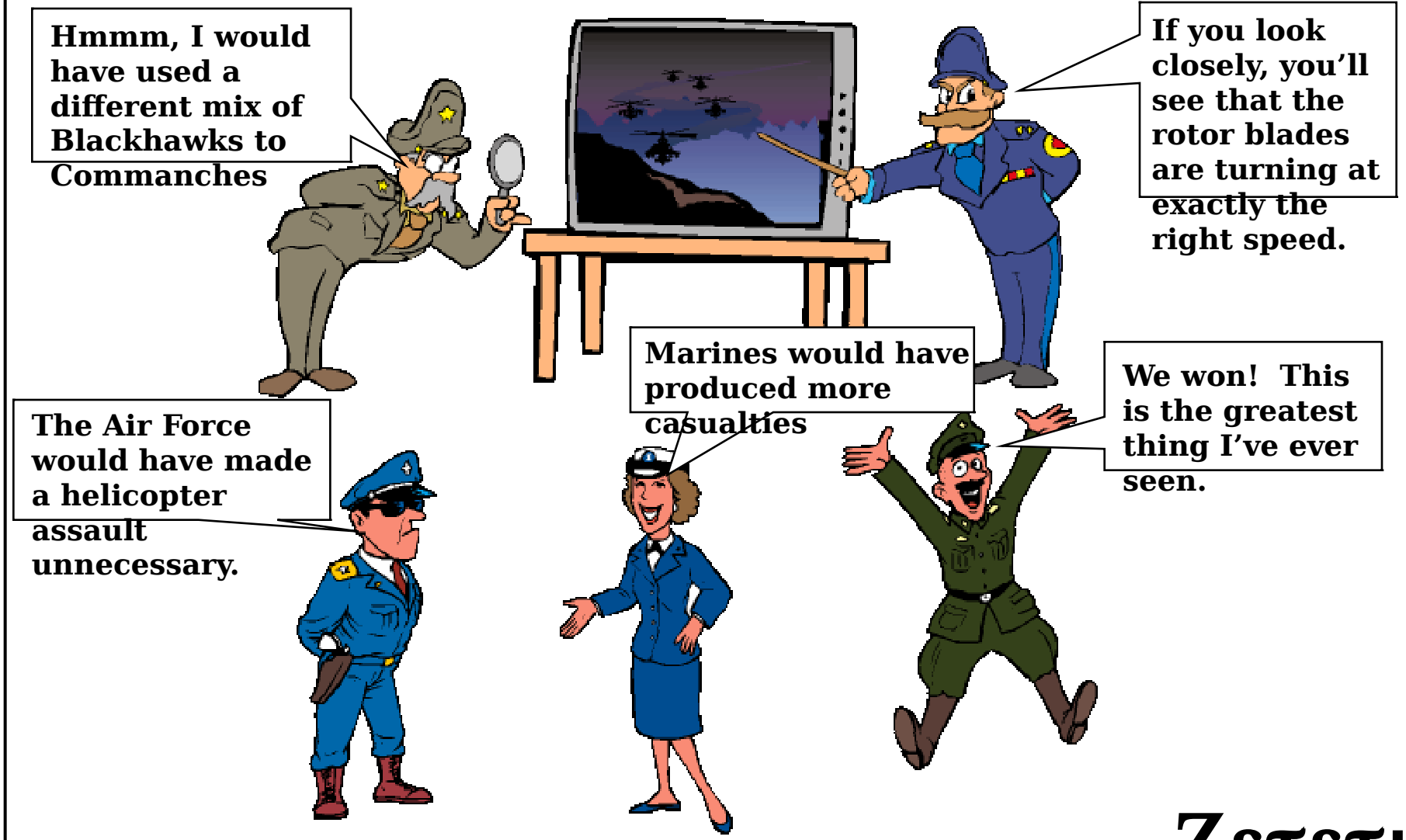
Results Validation: A Common Scene Is Seen in HBR Results Validation



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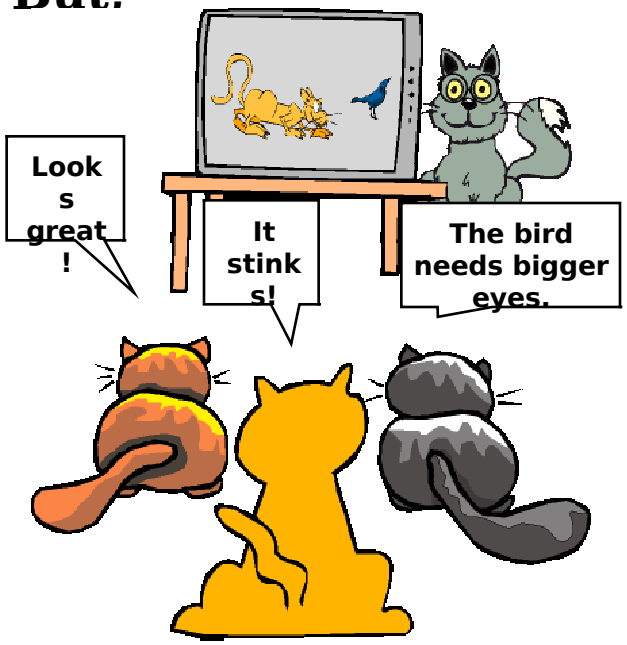
Results Validation: Simulation Results Supply the Most Direct Capabilities Visibility

Actual results produced by an HBR completely integrated with its simulated world create the last, most important and, often, most accessible depiction of that simulation's capabilities.

But.



- **Practical results validation cannot exhaustively explore the behavior spaces generated by the integrated HBR/simulated world.**
- **Sampling HBR behavior spaces for results validation has poorly understood consequences upon assessment reliability and utility.**
- **SME assessments tend to inextricably couple requirements, referent and capabilities information thus severely complicating their interpretation.**
- **SME validity opinions can vary widely, even conflict, and frequently do.**

Even for simulations of well understood physical phenomena, much of existing results validation relies primarily upon the subjective opinions of SMEs.

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Results Validation: Powerful Credibility Issues Shape HBR Results Validation

- **No User will ever consider an HBR valid without some level of integrated testing and validation of those results.**
- **HBRs must be tested when completely implemented and integrated with other simulation components, when they can produce their most complex behavior.**
- **Integrated testing must characterize the behavior space that the Users will use in their day-to-day operations.**
- **Any steps that can reduce testing complexity and improve testing results will improve HBR validation.**

Results validation is the least complete means of validation. Each scenario only supplies information on the system behavior over a single path or behavior thread. Extrapolating the validity of that information to other untested behavior threads, unless their relationships are formally understood, is both dangerous and unjustified especially for complex areas in the behavior space.

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Results Validation: Two Problems Severely Complicate HBR Results Validation

- **High functional complexity makes data collection difficult**
- **Directly observable behavior that provides very limited insight into internal functions makes data analysis difficult**

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Results Validation: Complexity Underlies the Core of the Data Collection Challenge

HBR Characteristic	Implication
very large space of possible behaviors, even for simple HBRs	visiting all points in the behavior space is infeasible to impossible
generally nonlinear surfaces that constrain possible behavior	meaningful sampling and interpolation is difficult to impossible
stochastic knowledge elements or behavior moderator models	oversampling is necessary to sufficiently characterize distributions
behavior very sensitive to initial & boundary conditions thereby making it chaotic	validation results are very sensitive to the scenario and data collected

Thus, theoretically, the only way to completely validate an HBR from its results is to experimentally drive over every possible path in its behavior space.

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Results Validation: Behavior Explanation Capabilities Are Essential for HBR Results Validation

- **A behavior auditing, tracing or explanation capability (a capability that identifies every dependency execution that precipitate each observable action and all of the conditions leading to those executions thus enabling detailed examination of the causal threads underlying the observable actions) is crucial to both HBR development and validation.**
- **Without explanation traces, it is impossible to know for sure what is occurring and why. For example, it helps to identify when**
  - **Correct behaviors occur for the wrong reason and**
  - **Incorrect behaviors occur as a result of the unexpected synergy of intersecting dependencies.**
- **Only behavior explanation can provide the insight necessary to determine if observed aberrant behavior truly results from design or implementation errors or if it represents acceptably realistic behavior.**
- **The Developer should be encouraged to incorporate behavior explanation technology as an integral part of the HBR if they had not intended to do so.**
- **Behavior visualization tools can also be useful but their output can be deceptive and must not substitute for detailed behavior trace analysis.**

The artificial intelligence community has developed very sophisticated behavior explanation technology for a number of different knowledge representations.

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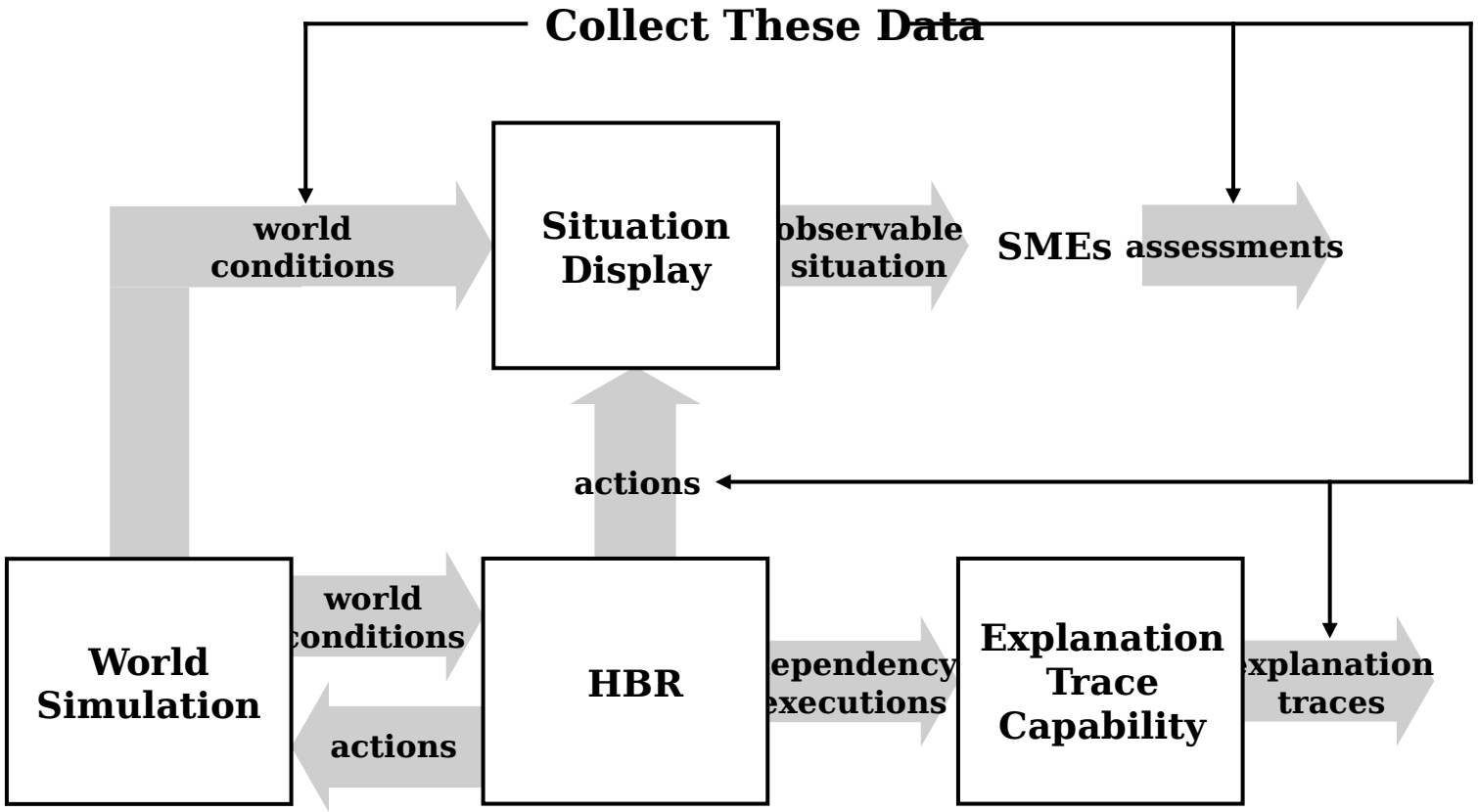
Results Validation: Collect Data at Several Points in Each Scenario



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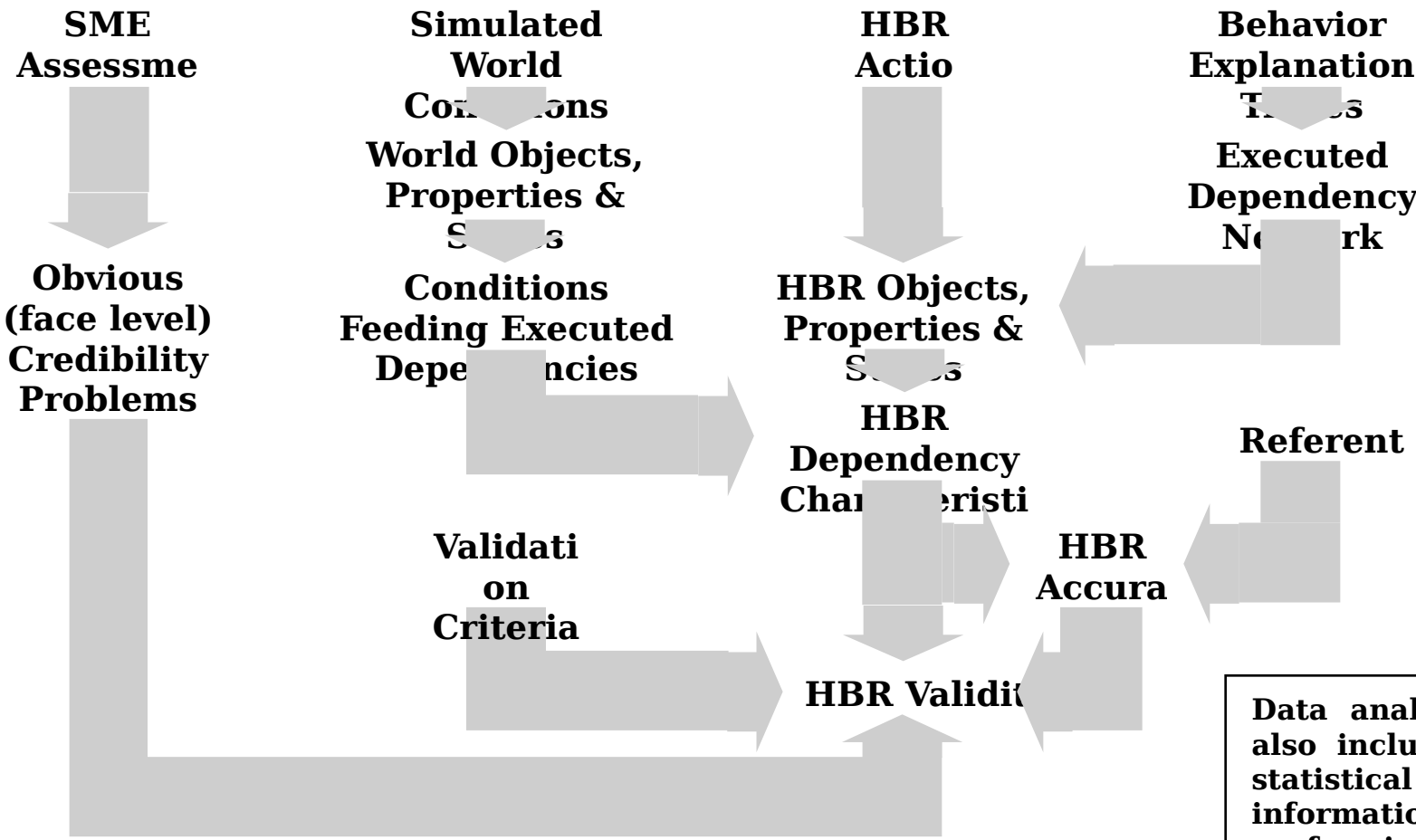
Results Validation: Systematic Data Analysis Leads to Rational HBR Validation Assessments



Data analysis should also include deriving statistical information and performing statistical tests to assess confidences.

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Results Validation: How Can Problems Detected in Results Validation Be Resolved?

- Redefine the problem behavior as a feature of the simulation, one that more accurately represents the idiosyncrasies of human behavior.
- Conduct further testing to define the limits of the problem then document the problem area and its limits. The user can then avoid excursions through this part of the behavior space through judicious design of their operational scenarios.
- Modify the contents of the knowledge base to correct the anomalous behavior.
- Modify components of the behavior engine to correct the problem.
- Modify both the behavior engine and the knowledge base to correct the problem.

Notes:

1. The extent of the anomalous behavior and the degree to which the users can tolerate that behavior largely determine the option that best suits the situation.
2. Changing the operational scenarios may only require additional validation effort if those changes drive the HBR into parts of its behavior space that have not been validated for the current purpose.
3. Any modified areas and all those to which they are coupled must then be re-validated to assure resolution of the problem and that the fix created no new problems. Repair or even diagnosis of problems in complex HBRs may be extremely difficult. If this situation imposes unacceptable cost or schedule risk then the other alternatives may be explored.
4. The user should be involved in making these decisions so they clearly understand what HBR capabilities will be delivered to them.

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Discussion: Special Challenges for HBR Validation

- Poorly formulated requirements
- Evolutionary development processes
- Conflicting subject matter expert judgments
- Non-intuitive knowledge representations (e.g., neural networks)
- Multi-paradigm reasoning approaches
- Learning systems
- Effects of behavior moderators
- Interoperability issues and validity
- Estimating and managing HBR validation costs

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Summary: State of the HBR Validation Technology Available Today

Validation Component	Conceptual Model	Knowledge Base	Observable Behavior
Requirements Characterization	nothing specific	limited formal languages	nothing specific
Referent Description	SMEs, physiol., psych. & sociol. models	SMEs, documentation	SMEs, experimental data
System Characterization	nothing specific	KB languages, NL explanations	observable behavior, explanation traces, performance meas.
Comparison Techniques	nothing specific	SMEs, KBS VV&E tools & techniques	SMEs, KBS testing tools & techniques

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